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Analysis

Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework

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ABSTRACT

The green economy, circular economy and bioeconomy are popular narratives in macro-level sustainability discussions in policy, scientific research and business. These three narratives offer three different recipes to address economic, social and ecological goals, thus promoting different pathways for sustainability transformations. We employ the well-known Framework for Strategic Sustainable Development (The Natural Step Framework) to comparatively identify the relative and integrated contribution of the three narratives for global net sustainability. We conclude that none of the three narratives, individually, offer a comprehensive 'package' of solutions. However, when considered jointly as collaborative narratives, they point towards a society and economy based on renewable/reproductive and biodiversity-based/benign processes, delivering material and immaterial benefits that fulfil the economic and social requirements of all people now and in the future. While the complementary understanding of the circular economy, bioeconomy and green economy provides important guidelines for sustainability transformations post-Covid-19, there is a need for more holistic, systems-wide and integrative research work on potentially competing or supplementary sustainability narratives. This type of work of clarification and synthesis is relevant to a wide range of scholars and professionals, since the conceptual understanding of sustainability narratives informs practical implementation through strategies, actions and monitoring tools, in public and private decision-making.

1. Introduction

The 17 Sustainable Development Goals set forth by the United Nations in 2015 have renewed a global vision to address sustainability challenges, and emphasized the urgency for concerted efforts by multiple societal actors. Over the past decades, '[s]ustainability science has attracted tens of thousands of researchers, practitioners, knowledge users, teachers and students from diverse institutions and disciplines from across the world […]. That diversity alone sets it apart from many other scientific fields' (Global Sustainable Development Report, 2019) (p. 120). Sustainability science is thus inherently inter- and transdisciplinary, and necessitates collaboration with societal stakeholders (Lu et al., 2019; Mihelcic et al., 2003). This is fundamental in tackling the prevailing unsustainability as a complex phenomenon. Consequently, the diversity of concepts, approaches, instruments and indicators, or, in other words, the 'sustainability tool box' is increasing rapidly (Broman and Robèrt, 2017; Lu et al., 2019; Robèrt et al., 2013, 2002).

While the long-term evolution of such a toolbox may be an asset for sustainability transformation, in the short term, the sustainability community would benefit from a coherent and logical knowledge base. The diversity of ideas, views and interests can make practical public and private actions difficult to implement. From the tool-user's perspective, different concepts, approaches and instruments may seem to be in

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competition or conflict with each other, and ultimately, action requires at least some kind of evidence-based consensus among the decision-makers. Existing knowledge should be applied in a strategic and complementary manner, considering and integrating different concepts, approaches, tools and instruments (Bastianoni et al., 2018; Little et al., 2016; Lu et al., 2019) towards a common goal of global net sustainability.[1] Hedelin argues that the existing complexity should be embraced, and that models are needed for 'connecting general understandings of SD [sustainable development] (SD theory) to specific practices' (Hedelin, 2019) (p. 743). Such works of synthesis, however, remain scarce in the sustainability science literature.

This article contributes to address a specific area of this gap. We focus on the integration of the green economy, the circular economy and the bioeconomy (GE, CE and BE). These three address, with different formulas, the global challenge of simultaneously meeting economic, social and ecological goals. Therefore, they can be understood as 'narratives' (as defined in D'Amato, 2021), serving an ancillary role, rather than a substitute one, for sustainable development (Borel-Saladin and Turok, 2013; Ferguson, 2015; Luederitz et al., 2017). The three narratives have received worldwide attention during the past decade (Borel-Saladin and Turok, 2013; Dietz et al., 2018; Murray et al., 2015), and are being developed through the joint engagement of the policy, practitioner and academic communities. Their communicative and implementation power currently supports the work performed by various societal actors in diverse realms and sectors, with renewed emphasis after the Covid-19 crisis (Korhonen and Granberg, 2020; Palahí et al., 2020; Taherzadeh, 2021). However, the narratives have been developed and largely used in a siloed manner, and often disjointed from the overarching framework of strong sustainability or global net sustainability (Kirchherr et al., 2017; Merino-Saum et al., 2020; Pfau et al., 2014).

Abundant literature exists examining the individual narratives of CE, GE and BE, also from a critical perspective (Bugge et al., 2016; Kirchherr et al., 2017; Merino-Saum et al., 2020). However, only few recent studies have comparatively addressed two or more of them (e.g. Bennich and Belyazid, 2017; Carus and Dammer, 2018; D'Amato et al., 2019, 2017; Giampietro, 2019; Loiseau et al., 2016; Palahí et al., 2020; Stegmann et al., 2020). Recently, Palahí et al., 2020 have proposed that a nature-based circular bioeconomy offers solutions to transform industrial sectors, rethink cities as well as land, food and health systems, and promote participation and a more equitable distribution of prosperity. This provides momentum for a comparative analysis of GE, CE and BE.

The main aim of this article is thus to *synthesize and evaluate the relative and integrated value of the narratives of green, circular and bioeconomy, within a strategic sustainability framework.* By 'strategic' we mean that all activities, measures and practices contribute to the goal of global net sustainability, in a mutually supportive and complementary manner.

We make use of the commonly known Framework for Strategic Sustainable Development (FSSD) (Broman and Robèrt, 2017; Robèrt et al., 2013; Robèrt et al., 2002), which we deem a particularly suitable method to systematize the comparison of the three narratives. The FSSD is composed of five interdependent levels of analysis that allow clarify 'the inter-relationships between phenomena of fundamentally different character' in the context of planning and leadership/management (Broman and Robèrt, 2017, p. 22). The interdependent levels allow to set up an operational procedure for pursuing global net sustainability. According to the above mentioned authors, the framework can be beneficial for organization and structuring any effort in the context of sustainability. Our specific research questions for this study are as follows.

1. What is the respective added value of GE, CE and BE as sustainability narratives?
2. Can GE, CE and BE be integrated in a strategic manner, and how can their joint application advance global net sustainability?

GE, CE and BE are cross-cutting in sustainability science and practice, and are used to frame sustainability challenges and to operationalize solutions by individuals, organizations and authorities at local, national and international level. We thus deem the implications of this study to be of value for a broad range of professionals, including scholars, practitioners and decision-makers.

2. Conceptual background

The well-recognized FSSD, also known as 'The Natural Step Framework', has been developed to make sense and make progress in the presence of a multitude of sustainability concepts, approaches, tools and indicators (Robèrt et al., 2013; Korhonen, 2004; Marshall and Toffel, 2005; Ny, 2009). It suggests that existing sustainability knowledge (concepts, approaches and tools) should inform action in a strategic manner towards sustainability, i.e. not as each other's substitutes nor competitor. The framework is complementary with the nine Planetary Boundaries (Pbs) (Robèrt et al., 2013; Rockstrom et al., 2009; Steffen et al., 2015). The FSSD includes five interdependent levels of analysis, planning and management (Fig. 1), from the most general/abstract to the particular/practical: 1. focus system; 2. goal; 3. strategies; 4. actions; and 5. tools and indicators.

The first level of the FSSD regards the social and ecological functioning of the system, or in other words, the 'rules of the game'. These include, for instance, the law of conservation of mass, the laws of thermodynamics, the solar dependency of biogeochemical cycles, the interactions and inter-relationships among biotic and abiotic elements of ecosystems, the stability and resilience of ecosystems and society's dependence on ecosystems. The second level represents the overall goal or end-state; while there is no globally shared understanding of the goal, in terms of global net sustainability, the authors of the FSSD provide four objectives to consider (Broman and Robèrt, 2017; Robèrt et al., 2013, 2002). Although they have been revised over the last 30 years or so, for the sake of the argument of our paper, we provide a summary in Fig. 1. The goal is not deterministic, but a state of continuous and evolving development; it includes sub-goals or objectives regarding the state of the environmental, social and economic dimensions in space and time.

The third level is about the strategies guiding public and private decision-making (e.g. well-recognized environmental management principles, coordination of governance processes). The fourth level is about the concrete actions and measures adopted to implement the concepts (e.g. production of renewable energy; reduction of waste; maintenance of ecosystem functionality and diversity). The fifth level includes tools and indicators to measure the success of the strategies and actions, as well as of the tools and indicators themselves.

3. Methods

The two research questions in this article (Section 1) are addressed in two analytical steps. As a first step, in order to capture the essence of GE, CE and BE, we identified ten relevant scientific articles (reviews, conceptual analyses) for each narrative, among the most cited documents (i.

[1] We define global net sustainability as follows: if an individual sustainability approach, concept, tool or instrument is applied in a certain project in a certain time and in a certain place, and sustainability gains are achieved, this does not result through complex systems feedback mechanisms into a situation that, somewhere else in the focus system 'society within biosphere' now or in future, negative sustainability impacts increase as a result. Global net sustainability is understood in the context of strong sustainability (Daly, 1996; Folke et al., 2016; Korhonen, 2006; Rockstrom et al., 2009), which acknowledges that the economy and society always function as sub-systems of the biosphere (in turn, weak sustainability allows for absolute environmental and social burdens to increase if the relative per-unit economic output burden decreases).

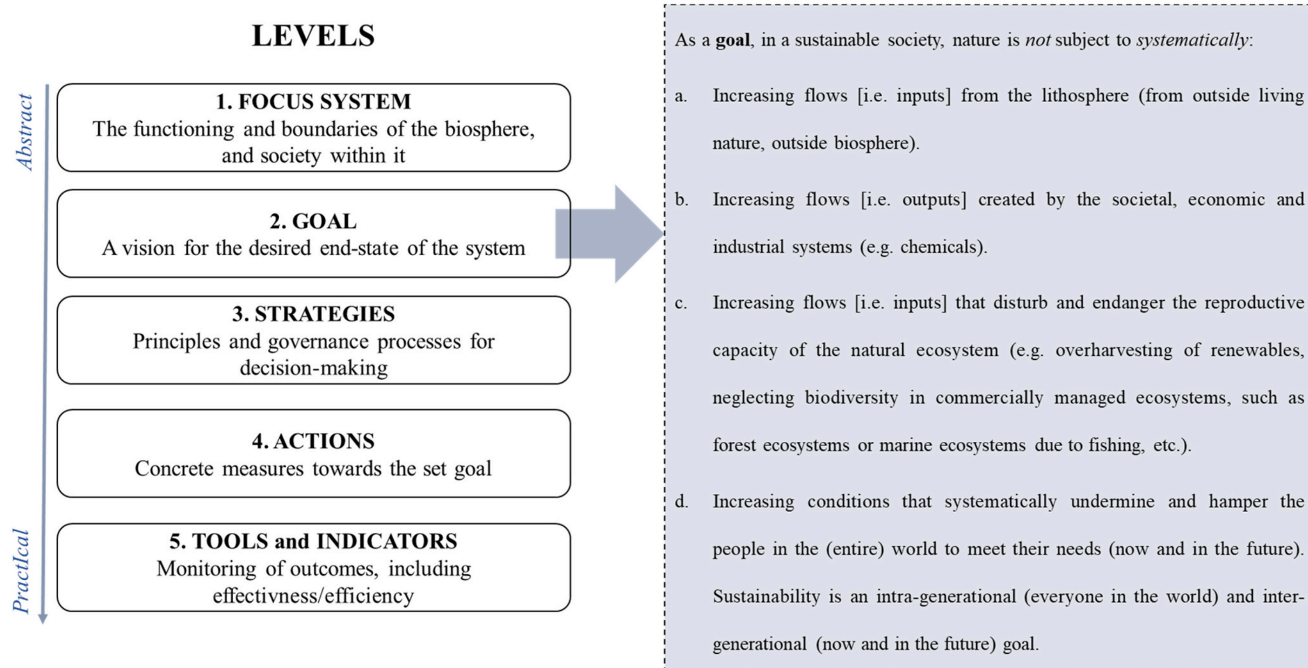

Fig. 1. The Framework for Strategic Sustainable Development (FSSD), including five interdependent levels of analysis, planning and management. The goal, i.e. the desired end-state of the system towards sustainability, is composed of four objectives. Modified from Broman and Robèrt (2017); Robèrt et al. (2013, 2002).

e. a total of thirty peer-reviewed articles). To do so we used Scopus, and in Autumn 2019 we searched for the following strings in the abstract, title and keywords, with no time limit: "green economy" AND ("review" OR "concept"); "circular economy" AND ("review" OR "concept"); "bioeconomy" AND ("review" OR "concept"). We only selected articles reviewing or discussing the narratives at a general level, excluding, for instance, documents focusing on a specific or technical topic, country (regional analyses were instead accepted) or economic sector. We prioritized the articles that received the most citations, and eventually determined that a number of ten articles for GE, CE and BE respectively would suffice to outline an accurate yet critical overview and summary. As these were very dense conceptual and critical analysis, we observed a saturation of information. We were able to confirm saturation based on our experience with GE, CE and BE (D'Amato et al., 2017, 2019; D'Amato, 2021; Korhonen et al., 2018a, 2018b).

We read the documents thoroughly and synthesized the general understanding of GE, CE and BE, focusing on the following elements: the historical roots, the set of solutions envisioned by the narrative, the conceptual diversity and the criticisms and limitations flagged by the scientific community (results in Section 4.1). We are aware that these are highly fluid and debated narratives across space and time. However, for the purposes of a comparative analysis, it is necessary to reify these narratives into crystallized definitions. We have mitigated this issue by drawing consistently from the critical research and coining the most comprehensive definitions (Tables 1 and 2) for each narrative, in light of the idea of global net sustainability.

As a second step, we compared GE, CE and BE against a strategic framework for sustainability. To this end we employed the Framework for Strategic Sustainable Development (Broman and Robèrt, 2017; Robèrt et al., 2013; Robèrt et al., 2002). In order to embed GE, CE and BE in the strategic framework, we referred to a wide body of literature from multiple disciplines, summoned through numerous and extensive ad hoc searches. We selectively searched for information that would inform the position of each narrative against the five level of the FSSD. We could here also rely on our previous research experience with GE, CE and BE to guide and inform our search and analysis. We deemed that further systematizing the literature search would have not provided any meaningful contribution to fulfilling the aims of this study, which required an in-depth conceptual analysis instead.

4. Results

4.1. A synthesis of the green, circular and bioeconomy

4.1.1. The green economy

In addition to promoting low-carbon (abiotic, lithosphere-originated) energy, GE advocates that ecological processes occurring in natural and semi-natural systems can be leveraged to the benefit of human beings without jeopardizing the sustainability of these ecosystems. Such beneficial ecological processes, namely, ecosystem services largely support the functioning of our economy and society, but are often invisible or disregarded.

While already present in the scientific literature for decades, interest towards GE was renewed following the RIO + 20 conference in 2012, with a strong political drive by the United Nations (Loiseau et al., 2016), as well as by international institutions such as the Organization for Economic Co-operation and Development (OECD), the International Monetary Fund (IMF), the World Bank, World Trade Organization (WTO) and the World Business Council on Sustainable Development (WBCSD) (Ferguson, 2015; O'Neill and Gibbs, 2016). The GE momentum was connected to the 2008 financial crisis, with the idea of redirecting public and private capital to finance green activities rather than the business-as-usual brown economy (Borel-Saladin and Turok, 2013; Brand, 2012). Green activities include solutions to 'reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services' (UNEP, 2011) (p. 1). The UNEP definition states that GE 'results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive' (ibid.). Poverty reduction and social equity are also relevant issues in GE. Rural poor, especially in emerging economies, are largely dependent on ecosystem services. Thus conservation and restoration of natural and semi-natural systems can reduce poverty and

Table 1
A comparative overview of the green, circular and bioeconomy (GE, CE BE), based on the Framework for Strategic Sustainable Development (FSSD) (modified from Broman and Robèrt (2017); Robèrt et al. (2013, 2002)).

FSSD levels	Strategic framework	GE's stance	CE's stance	BE's stance
1. The focus system	Social and ecological constitutional boundaries and system functioning, e.g. thermodynamics; resilience properties of complex adaptive systems; the dependence of biogeochemical cycles on solar energy; interdependencies of biodiversity levels; societal dependency on and exchange with the biosphere.	Recognition that the society and economy inevitably depend on the global biosphere; spatial and temporal trade-offs between ecosystem services and societal goals recognized, but in conflict with the belief that win-win-win solutions can always mitigate them; in practice some weak sustainability stances occur (e.g. leakage, rebound). No explicit reference to decoupling prosperity from resource use.	Some degree of recognition that the society and economy inevitably depend on the global biosphere; thermodynamics of energy and material recognized, but in conflict with the belief that full circularity is achievable; temporal and spatial trade-offs between societal goals recognized, but in practice some undesired effects occur (e.g. leakage, rebound). No explicit reference to decoupling prosperity from resource use.	Some degree of recognition that the society and economy inevitably depend on the global biosphere; spatial and temporal trade-offs between provisioning and other ecosystem services recognized, but remain unaddressed; in practice some weak sustainability stances occur (e.g. leakage, rebound). No explicit reference to decoupling prosperity from resource use.
2. Goal	Desired end-state of the system, i.e. no increase in: inputs from lithosphere or from ecosphere; outputs from societal, economic and industrial systems; conditions that systematically undermine and hamper meeting people's needs worldwide, now and in the future.	Enhancing material and immaterial benefits from the biosphere (ecosystem services) to address human well-being, employment and poverty alleviation; reducing lithosphere inputs through substitution of fossil energy with abiotic renewable energy.	Reducing *(in absolute terms*[a]*)* of inputs and outputs in production/ consumption systems by retaining material and energy flows within high value/functionality levels for as long as possible; improving social conditions through job creation and regional development.	Substituting lithosphere inputs (i.e. fossils) with biosphere inputs (living biomass) in economic activities; improving social conditions through job creation and regional development.
3. Strategies	Most relevant principles and governance processes for implementation.	Coordination of regulatory processes, public and private financial support (emphasis on market-like schemes), voluntary standards or practices, market-demand; Particularly relevant principles: polluter/beneficiary pays.	Coordination of regulatory processes, public-private financial support, voluntary standards and practices (emphasis on industry collaboration), market-demand; Particularly relevant principles: avoid lock-in; responsibility in efficiency/ effectiveness of resource use.	Coordination of regulatory processes, public-private financial support (emphasis on research programmes and green procurement), voluntary standards and practices (emphasis on industry collaboration), market-demand; Particularly relevant principles: precautionary principle; avoid lock-in; responsibility in effectiveness/ efficiency of resource use.
4. Actions	Concrete measures towards the desired end-goal.	Assessment and accounting of ecosystem services, restoration and maintenance of ecosystems, development of nature-based solutions and green infrastructures.	Improvement of material and energy performance; product reuse and remanufacturing preferred over traditional recycling; product sharing and multi-functionality preferred over ownership and mono-functionality.	Development and marketization, through knowledge and technology, of innovative and high-value goods and services from the potential held in biological resources, while ensuring sustainable sourcing and efficient resource use[b].
5. Tools and indicators	Monitoring of the effectiveness and efficiency of strategies and actions, as well as tools and indicators themselves.	Biophysical assessments (field observations and experiments, remote sensing, modelling or expert-based considerations); social valuation (e.g. surveys, questionnaires, ethnographic methods, focus groups, analysis of secondary statistics and documents, scenario analysis, multi-criteria analysis, citizens' juries); monetary valuation (market price, production function, avoided damage/ replacement cost, hedonic pricing, travel cost, contingent valuation, choice modelling). Example of aggregated metrics: Global Green Economy Index; Green growth indicators framework; Natural Capital Index; System of Environmental-Economic Accounting.	Approaches to assessing sustainability impacts of all economic activities, e.g. input-output analysis, total material flow method, life cycle approaches, substance flow analysis, material flow accounting, eco-balances, ecological/ carbon/water footprints. Example of aggregated metrics: Circularity rate; Material Circularity Indicator.	A range of approaches, from approaches to the assessment of bio-based content and of sustainability impacts of economic activities (e.g. input-output methods and LCA approaches) to multi-criteria or cost-benefit analysis. Aggregated metrics: under development.

[a] Not explicitly recognized across all CE literature.
[b] Not explicitly recognized across all BE literature.

vulnerability (Borel-Saladin and Turok, 2013).

According to its mainstream advocacy, GE activities are to be implemented – when appropriate – through markets (e.g. investments/ divestments, taxes/incentives, payments and compensations) and voluntary approaches (e.g. certification and standards), jointly with regulatory and other policy instruments (Borel-Saladin and Turok, 2013; Luederitz et al., 2017). These include measures such as investments in non-fossil (generally abiotic-originated) and efficient energy production and consumption; divestments from perverse subsidies for fossil fuels or unsustainable land use management practices; nature resource management and pricing, including carbon or water pricing, carbon tax and carbon sequestration projects, and payments or compensations for ecosystem services (Barbier, 2012). GE also hosts some elements of CE, such as reduction of material and energy inputs in production process, recycling and reuse, greener supply chains or shared ownership (Loiseau et al., 2016; Lorek and Spangenberg, 2014).

Table 2
The respective contribution of GE, CE and BE to the four objectives (a-d) articulated in the second level of the Framework for Strategic Sustainable Development, i.e. goal or desired end-state of the system.

Goal objectives	GE	CE	BE
a. Inputs from the lithosphere	Promotes renewable energy sources, especially abiotic.	Aims at relative or even absolute decrease of virgin, abiotic and biotic inputs – and consequently, the decrease of societal outputs – within the global economy.	Envisions a decrease in abiotic inputs (especially fossil resources), compensated by the extraction of biotic resources to support the global economy.
b. Societal outputs	Envisions a reduction in pollution and emission, but does not clearly address overconsumption.		Places little emphasis on the biodegradability and toxicity of bio-based products and activities compared to traditional alternatives, and on overconsumption.
c. Inputs from natural and semi-natural ecosystems	Advocates for maintaining and enhancing multiple ecosystem services as foundational to human well-being.	Fails to integrate the role of natural capital and ecosystem services, and remains strongly resource-oriented.	Recognizes the role of natural capital and ecosystem services, but remains strongly resource-oriented.
d. Conditions that hamper meeting inter and intra-generational needs	Advocates for improved human well-being, poverty alleviation and social equity.	Targets employment and regional development, but remains limited in addressing regional and global inequalities.	Targets employment and development, especially in rural areas and in regional bioclusters, but remains limited in addressing regional and global inequalities.

One source of criticism is the level of self-organization required, according to which multiple actors (especially economic agents) co-develop GE solutions. There is a need for 'coordination, regulation and accountability' (p. 198) of large scale transformations (Caprotti and Bailey, 2014) in order to avoid phenomena such as rebound or leakage effects (i.e. 'green' gains may be offset by 'browning' in time or space). GE is also criticized by some scholars as 'an essentially neoliberal project aimed at placing market logics firmly at the center of socio-technical transitions to sustainable and low carbon futures' (Caprotti and Bailey, 2014) (p. 196). In other words, the limitations of GE include its strong focus on technological and market-based solutions for green growth, which are considered insufficient to address current sustainability issues, and are sometimes identified as co-causes of the problems (Borel-Saladin and Turok, 2013; Brand, 2012; Luederitz et al., 2017). GE is thus criticized to be insufficiently radical in advocating for transformational rather than adaptive strategies (Lorek and Spangenberg, 2014). For instance, individual behavior of citizens and consumers, and consumption patterns remain an important, yet only peripheral, issue (Caprotti and Bailey, 2014; Lorek and Spangenberg, 2014). Some authors have highlighted a co-presence of multiple understandings of GE, coupled both with green growth and weak sustainability, as well as with limits to growth/post growth ideas characteristic of strong sustainability (Ferguson, 2015).

4.1.2. *The circular economy*

Defined in opposition to the dominant and prevailing global linear economy in terms of the physical flows of materials and energy (Sauvé et al., 2016), CE aims at supporting the development of regenerative production-consumption systems, where inputs and outputs are minimized by 'slowing, closing, and narrowing material and energy loops' (Geissdoerfer et al., 2017) (p. 759) (although it must be noted that the energy loop can never be closed completely). CE conceptualization has multiple contributors from and beyond academia (Winans et al., 2017), and has received renewed interest in the past decade in science, business, policy-making and other societal realms (Blomsma and Brennan, 2017; Geissdoerfer et al., 2017; Ghisellini et al., 2016). Its roots are in the ideas of industrial ecology and industrial ecosystems. While originally perceived in terms of cost reduction for industrial and business development, after the 1960s CE acquired a new relevance due to emerging issues of resource overconsumption and pollution (see the 'Spaceship earth' metaphor). Currently, the conceptualization of CE is largely driven by the practitioner community, embodied by the Ellen MacArthur foundation in particular. At the political level, CE is promoted in the EU and several other nations. A notable example of national regulatory framework on CE was established in China in 2008.

Overall, CE emphasizes the enhancement of the value embedded in material and energy (Korhonen et al., 2018a), leveraging diversity and resilience as well as system thinking in production-consumption processes (Lewandowski, 2016; Sauvé et al., 2016). CE should be achieved through improving the material and energy performance of production processes and product usage along the product life cycle. Cycles and cascades are encouraged within the same industrial process or across industries or other uses. This means that energy and material should not be released to the environment before they can be used for lower quality uses. CE solutions thus include rethinking product/services design so to allow for, e.g., efficiency gains; reduction of material and energy needed for production; long-term maintenance and repair; sharing, reuse, refurbishing and remanufacturing, repurposing; recycling and reclassification of waste into inorganic and biological components; and renewability of energy sources (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kirchherr et al., 2017). More radical stances on CE also include refusing to produce superfluous or redundant products or services.

The scientific and research approach to CE is rapidly evolving (Korhonen et al., 2018a). However, a large part of the literature on CE seems to focus more on recycling compared to other solutions, with few references to the waste hierarchy principle, which sets priorities for waste management - from prevention to disposal (Kirchherr et al., 2017). In addition, there seems to be a prioritization of the economic system (ibid.), with 'primary benefits for the environment, and only implicit gains for social aspects' (Geissdoerfer et al., 2017) (p. 764). The social dimension of sustainability is also not always explicitly addressed in CE (Murray et al., 2015). The social aspects usually mentioned refer to job creation or fairer taxation (Geissdoerfer et al., 2017), while other societal issues are neglected (Kirchherr et al., 2017). Murray et al. (2015) (p. 376) state that '[i]t is unclear how the concept of CE will lead to greater social equality, in terms of inter- and intra-generational equity, gender, racial and religious equality and other diversity, financial equality, or in terms of equality of social opportunity'.

Furthermore, while perpetual loops may be desirable, there are technical, economic and ultimately physical limitations (Andersen, 2007). For instance, eco-efficiency, i.e. lowering the per-unit-production costs and impacts, may produce a rebound effect, increasing production and consumption levels, and thus reducing or cancelling out the net environmental benefits of the total environmental burden. Even the alternative idea of eco-effectiveness, which pursues a net positive environmental benefit, is still vulnerable to leakage, i.e. unintended or unaccounted negative consequences in other stages of the life cycle (Sauvé et al., 2016) or in other countries (Korhonen et al., 2018a). Recent literature has pointed out that CE cannot solely leverage technological solutions; societal and institutional restructuring is needed in order to avoid path dependencies and lock-ins, including 'inter-sectoral, inter-organizational and inter-life' changes (Korhonen et al., 2018a) (p.

41). A new culture of consumption and benefit distribution is also called for by some through dematerialization (servitization, sharing, digitalization, and virtualization) and possibly sufficiency (Korhonen et al., 2018a). Even though not excluding compatibility with degrowth ideas, CE does not explicitly align with them (Ghisellini et al., 2016).

4.1.3. The bioeconomy

BE, at times also called 'bio-based economy' or 'knowledge based bio-economy', leverages the potential of biological resources from land and sea for the development and commercialization of goods and services; it thus proposes the substitution of fossil-based activities with those based on living biomass, with biotechnology and knowledge-based innovations driving this process. This includes technology to convert biomass into various products, from bioenergy and fuels to paper and commodities, as well as textiles, chemicals and pharmaceuticals; to create solutions for waste water purification and bioremediation; to improve crop performance using genetic manipulation; and to create new or more advanced pharmaceuticals (McCormick and Kautto, 2013). Bioeconomy products thus range from biomass-demanding, low-value products, such as biofuels, to high-value products requiring smaller biomass quantities, such as bio-based chemical or compounds. Although policy-driven, BE is received well at industrial level, especially in the forest and agricultural sectors, as a driver of renovation and development (McCormick and Kautto, 2013).

In the scientific literature, links to Georgescu-Roegen's work on bioeconomics are often mentioned as foundational to BE. BE is an increasing area of research, generally published in sector specific and technical journals. Accordingly, there is a diversity of understandings regarding BE, which can be summarised in three distinct visions (Bugge et al., 2016): a resource-oriented vision focusing on the potential of biological materials and energy from agriculture, marine, and forestry sources; a biotechnology vision concerning the application and commercialization of biotechnology; and a bioecology vision highlighting the importance of multiple ecological processes, agro-environmental and biosecurity and territorial adaptation.

Various scholars have, however, expressed concerns about the sustainability contribution of BE (Pfau et al., 2014). Key issues are the sustainability of biomass sourcing and the value of biomass uses (Fritsche and Iriarte, 2014). Increased biomass needs entails a certain level of land use intensification, thus exacerbating trade-offs between biomass production and the maintenance of ecological functions related to, among others, water, soil and biodiversity. The cascading principle of biomass suggests that the use of biomass resources should prioritize, when technically and economically feasible, the making of high-value products (e.g. biochemicals and pharmaceuticals) over low-value ones (e.g. bioenergy or biofuels) (Golembiewski et al., 2015).

Many of the drivers behind BE, 'the reduction of the dependence on fossil fuels, energy security or the expectation of economic benefits and rural development are […] mostly related to economic interests and not primarily sustainability concerns' (Pfau et al., 2014) (p. 1240). When considering European BE policies, the economic dimension prevails over the environmental and social dimensions (Ramcilovic-Suominen and Pülzl, 2018).

Similarly to GE (see Section 3.3.1), BE is criticized for being 'a promissory construct that is meant to induce and facilitate some actions, while deterring others' (Goven and Pavone, 2015) (p. 302). In particular, BE relies heavily on techno-scientific solutions, and promotes a 'neoliberal approach to the utilization of biological material and information' (Goven and Pavone, 2015) (p. 306–307). Some literature has thus pointed out to the commodification of biological resources through biotechnologies, including implications related to power relations, information ownership and to ethical issues (Birch and Tyfield, 2013; Helmreich, 2008).

Recently, policy and academic literature has suggested that BE can benefit from broader sustainability considerations (Giampietro, 2019; Liobikiene et al., 2019; Pfau et al., 2014). The EU updated BE Strategy (European Commission, 2018) states that '[c]ircularity is a quintessential element of the European Commission's vision for an EU Bioeconomy' (p. 49) and that '[f]or the bioeconomy to deliver on sustainability, we must be able to better understand and measure its effects and impacts on the ecological boundaries of our planet. This is necessary to develop the bioeconomy in a way that attenuates pressures on the environment, values and protects biodiversity and enhances the full range of ecosystem services' (p. 14). Similarly to GE and CE, BE does not present explicit stances on the issue of growth.

4.2. The green, circular and bioeconomy within a strategic framework

4.2.1. Level 1 - focus system

In CE, BE and especially GE, there is some level of recognition that the society and economy operate within the global biosphere (as proposed by Folke et al., 2016). Several sources and scholars acknowledge the role of renewable and non-renewable natural capital, biodiversity and the derived ecosystem services as underpinning CE and BE (e.g. Atanasova et al., 2021; Breure et al., 2018; Buchmann-Duck and Beazley, 2020; European Commission, 2018; European Environment Agency, 2018; Hetemäki, 2017; Liobikiene et al., 2019; The Ellen MacArthur Foundation, 2015; Global Bioeconomy Summit, 2018). Such role is recognized to be foundational to GE, as also highlighted by international initiatives such as The Economics of Ecosystems and Biodiversity (TEEB) (ten Brink et al., 2012). Notably, all three narratives hold a utilitarian framing of nature, meaning that nature is valued in light of the benefit that humans derive from it.

At least in theory, there is acknowledgment of spatial and temporal scales/boundaries and dynamic interdependencies (synergies, trade-offs) between the ecological, economic and social dimensions. In practice, however, leakage and rebound effects may still occur, depending on how the concepts are implemented. In the context of CE, for instance, eco-efficiency without responsible production/consumption can promote an increase in production/consumption (i.e. rebound effect). Similarly, carbon benefits from BE activities can be reduced by an increase in production/consumption, if BE activities are additional, rather than substitutes, to fossil-based ones. Conservation measures promoted in one country under GE policies can result in leakage, if externalities are exported elsewhere. Moreover, GE places a strong emphasis on the fact that trade-offs among ecosystem services and across sustainability dimensions can be mitigated by implementing win-win-win solutions, that allow the enhancement of multiple ecological and socio-economic values; it is however unlikely that this can be feasible under all circumstances.

The three narratives have no clear stance on desirable levels of substitution of different types of capital, e.g. manufactured capital vs natural capital (Daly, 1996). Compared to the GE, CE and BE are strongly resource-centered and largely overlook the trade-offs at land use level, including loss of biodiversity and related ecological processes.

The thermodynamics of energy and materials are recognized in CE, but the physical impossibility of absolute circularity, whether it is based on fossil or renewable resource, is not always explicit (Millar et al., 2019). In fact, energy is constantly required to support such circularity, and at some point, such transaction becomes economically or technically unfeasible. This problem also affects attempts at a circular bioeconomy (CEBE) (Carus and Dammer, 2018).

Existing literature suggests that neither GE, CE nor BE formally and clearly addresses the idea of decoupling prosperity from resource consumption (Giampietro, 2019; Kasztelan, 2017). The general understanding of the three narratives largely aligns with the position that environmental and social goals can be reconciled with economic growth, and technological solutions play a strong role in delivering the desired changes. However, scholars have been exploring compatibilities of GE, CE or BE and the limits of economic growth (D'Amato et al., 2019; Ghisellini et al., 2016; Giampietro, 2019; Hart and Pomponi, 2021; Kasztelan, 2017; Oliveira et al., 2021; Therond et al., 2017). In conclusion, there is awareness about the system under focus and its constituting 'rules', but cognitive dissonances persist. Table 1 proposes an overview of levels 1–5 of the FSSD framework, and the respective stances of GE, CE and BE.

4.2.2. Level 2 - goal

The FSSD has proposed four objectives to articulate level 2, i.e. the desired end-state of the system (see the objectives in Section 2). These include reduction of a. inputs from the lithosphere; b. societal output; c. input from natural and semi-natural ecosystems; d. conditions that hamper meeting inter and intra-generational needs. Table 2 shows how GE, CE and BE address each objective of the FSSD, including gap areas.

GE addresses objective a to the extent that it promotes abiotic renewable energy sources. Objective b, i.e. the issue of societal outputs, is addressed to a certain extent, as GE envisions a reduction in pollution and emission, but does not clearly address overconsumption. A stronger emphasis is placed on objective c. GE aims at maintaining and enhancing multiple benefits to human beings (ecosystem services) derived from natural and semi-natural systems. Ecosystem services research shows that trade-offs often occur between provisioning and other ecosystem services (e.g. maximization of timber production vs water resources) (Lee and Lautenbach, 2016; Smith et al., 2017). Therefore, the simultaneous maintenance of multiple services can be obtained either through a reduction of the current use of provisioning services (i.e. tangible natural resources) or through innovations in land management or in the artificial synthesis of biomass that would allow to mitigate or decouple such trade-offs (see production frontier (Hetemäki, 2017). This issue also remains central in BE. GE also addresses objective 4, with promises of job creation from 'green' activities (renewables, ecosystem services-based business) and of poverty alleviation, particularly in developing countries.

CE can contribute to objective a, b and c because it promotes change in production-consumption systems to pursue the relative or even *absolute* decrease of virgin, abiotic and biotic inputs (and consequently, the decrease of societal outputs) within the global economy. This is done by direct input reduction, and by secondary reduction through the establishment of cycling loops for resources (remanufacturing, reusing, refurbishing, repairing, recycling). Because of its technological orientation, currently a large part of CE literature only indirectly addresses the fourth objective. However, potential for contribution can be articulated in terms of job creation for reuse, remanufacturing, repair and refurbishment businesses, creating more value from the resources used, with – in theory – opportunities for value redistribution across societal actors, including local economies (often in developing countries) at the origin of the value chain. Note however that improved efficiency does not automatically lead to improved justice.

In BE, a trade-off occurs between objectives a and c, because the decrease in abiotic inputs (especially fossil resources) to support the global economy is compensated by the need to extract biotic resources. At the current state of the art, BE does not explicitly propose solutions for a net *decrease* of total inputs (abiotic + biotic), nor does it clearly address the issue of outputs. In fact, contributions to objective b are not explicit, as there is little empahsis on the biodegradability and toxicity of BE various products and activities compared to traditional alternatives. We can assume there can be a margin of improvement compared to the current system, should these issues be taken into consideration as the implementation of BE progresses. Like CE, there is no specific emphasis in BE on the social dimension; objective d thus remains largely unaddressed. *Potential* for contribution can be articulated in terms of job creation, especially in rural areas and in regional bioclusters; creating new value from bioresources, with – in theory – opportunities for value redistribution across societal actors, including local economies (often in developing countries) at the origin of the value chain. Note, however, that BE, as currently conceived, offers no concrete solution on how to shorten the distance between resource-producers (e.g. rural areas/ Global south), or resource-manufacturers and consumers (e.g. urban areas/developed countries).

4.2.3. Level three - strategies

Public and private decision-making is guided by generally recognized principles and implemented through governance processes and policy mixes (Kern et al., 2019). For example, the 'precautionary principle' and the 'just redistribution of resources principle' are well-known in public environmental management (Hedelin, 2019). Various actors contribute to the co-governance of sustainability challenges through different means. Governance can include state-driven regulatory processes (e.g. prohibition, laws), economic and financial instruments (e.g. investments, subsidies, taxes), and voluntary agreements and negotiations involving private actors (e.g. standards and certification) (IPBES, 2018). The implementation of CE, BE and GE is going to be more or less centralized depending on the country. However, it is possible to generalize that both top-down and bottom-up dynamics will be required, as well as the full range of governance processes available to steer public and private decision-making. Specific principles and processes can be isolated as being particularly relevant to GE, CE or BE.

While maintaining appreciation for regulatory governance processes, the implementation of GE strongly leverages the innovative and complementary role of economic instruments and voluntary participatory processes, emphasizing the mobilization of resources for green investments and for nature conservation (e.g. markets for ecosystem services). Relevant principles for GE are the 'polluter pays' and the 'beneficiary pays', respectively valid in the context of offsetting for carbon emission or biodiversity loss, and payments for ecosystem services.

Regulatory processes have been important in driving CE globally (with renewed emphasis in the European Green Deal), while the barriers outlined often include economic and market limitations (de Jesus and Mendonça, 2018; Kirchherr et al., 2018). There is some evidence suggesting that both environmental policy and market demand drive resource-efficient eco-innovations for a circular economy in EU firms (Cainelli et al., 2020).

National BE strategies 'rely heavily on soft regulatory means, such as self-regulation of global value chains through private standards and certification regimes' (Dietz et al., 2018) (p. 11), but little concrete policy measures apart beyond research programmes, at least in Europe (Töller et al., 2021). Regulatory frameworks, concurrently with public financial financial and capacity support for research and development, and company-driven customer and stakeholder engagement are called for (Wesseler and Von Braun, 2017). A combination of standard-setting and financial incentives (e.g. public procurement) could well support BE innovation niches, which might be more environmentally friendly but less economically competitive than traditional alternatives (Hetemäki, 2017; Morone and D'Amato, 2019; Philp, 2018).

For the more transformational visions of CE and BE, there is a need for a deeper societal and institutional restructuring (including a more participative role of consumers, users and citizens), as well as avoidance of path dependencies and lock-ins. CE and BE should respond to the principles of 'effectiveness and efficiency' of resource use (see the principles of waste hierarchy and of cascading use of biomass, respectively in sections 3.1.2 and 3.1.3). Moreover, according to the principle of 'responsibility', individual or groups accessing ecological processes and resources must ensure their long-term sustainability. The precautionary principle is relevant to BE with regard to the outputs of BE activities (waste, toxic materials) and biotechnology issues.

4.2.4. Level 4 - actions

In addition to promoting renewable abiotic energy, GE emphasizes leveraging the potential benefits delivered by living and dynamic natural ecosystems to human wellbeing. This is implemented by means of ecosystem conservation and restoration, nature-based solutions, green infrastructure development and biomimicry (ten Brink et al., 2012). Natural capital is seen as fruitful assets, benefiting various societal actors, from individuals to organizations. For example, earth systems engineering (Allenby, 2000) and ecological design (Costanza, 2012) suggest that investing in the preservation of original natural systems can be more cost-effective than restoring them or building artificial solutions (the latter being generally mono-functional, and reliant on land use change and fossil resources). Ecosystems provide multiple functions simultaneously (e.g. air and water purification, local and global climate regulation, soil maintenance, recreation, positive contribution to psycho-physical health) (Cohen-Schacham et al., 2016; Nesshöver et al., 2017).

CE promotes the high economic value and functionality of material cycles and energy cascades. This means that, at least in theory, reuse, remanufacturing, refurbishment and repair are prioritized. The traditional recycling for low raw material value, instead, should be a low-priority solution. Moreover, some scholars stress that there is a vast amount of available, already existing technical infrastructure, products and technology that is largely underused. and call for shared use over the current situation of individual consumption and ownership.

BE is concretized in the development and marketization of innovative products and services derived from renewable biological resources, rather than fossil ones. These range from low-value products such as biomass-based fuels (in substitution to coal, oil or natural gas); to commodity products such as textiles and furniture; to the construction industry, including multi-storey buildings; to biotechnology solutions such as anaerobic digestion for fertilizer production; to organism-mediated bioremediation; to higher-end products such as cosmetic and pharmaceutical applications (Toppinen et al., 2018). In principle, sustainability considerations would require to prioritize the use of biomass for food security, followed by higher value applications (Lewandowski, 2016).

At present, biomass is largely derived from forestry or agro-food systems and related residual and waste streams. To mitigate trade-offs between increasing biomass needs (including competing uses) and other ecosystem services at land use level, solutions envisioned include sustainable management practices, the use of marginal and abandoned land, improvements in the circular use of waste and residues, and alternative biomass sources (e.g. acquatic, fungi) (European Environment Agency, 2018).

4.2.5. Level 5 – Tools and indicators

Tools associated with measuring progress towards GE have been developed to account for invisible and undervalued ecosystem services and the trade-offs among them under different land management options (Müller and Burkhard, 2012). Methods for the assessment and valuation of ecosystem services range from biophysical measures to social and economic values. In other words, the value of ecosystem services can be expressed, qualitatively and/or quantitatively, through multiple methodologies. Biophysical assessment includes, for instance, field observations and experiments, remote sensing, modelling and expert-based considerations (Vihervaara et al., 2017). Monetary valuation includes market and non-market based methods, such as market price, production function, avoided damage/replacement cost, hedonic pricing, travel cost, contingent valuation and choice modelling (Baveye et al., 2016). More social-value oriented approaches include consultative, non-consultative and deliberative methods (e.g. surveys, questionnaires, ethnographic methods, focus groups, analysis of secondary statistics and documents, scenario analysis, multi-criteria analysis, citizens' juries) (Kelemen et al., 2016). As individual assessments are unable to capture the full spectrum of values associated with ecosystem services, the information from each kind of assessment is supposed to be combined and interpreted in a multi-layered and complementary manner.

Tools typically used in CE include, for instance, input-output analysis, total material flow method, life cycle approaches, substance flow analysis, material flow accounting, eco-balances and ecological/carbon/water footprints. Because they have traditionally been developed to monitor material/energy flows in consumption-production systems, these tools generally focus on a selected number of environmental indicators, such as carbon and greenhouse gases, water resources, nutrients and toxic compounds, which relate to impact categories such as climate, energy, eutrophication, acidification or human toxicity. Several scholars have called for integrating broader social and ecological issues in the already-existing methods (Alejandre et al., 2019; Othoniel et al., 2019).

Since BE proposes to leverage biomass resources as the main input of the industrial system, the relevant tools must be able to capture these biophysical and socio-economic value flows along the chain (Fritsche and Iriarte, 2014; Wesseler and Von Braun, 2017). Thus, BE can borrow from a mix of the tools mentioned for GE and CE, ranging from process-based approaches aimed at assessing sustainability impacts of economic activities (e.g. input-output methods and LCA approaches) to multi-criteria or cost-benefit analysis (Karvonen et al., 2017). A BE-specific analysis is the bio-based carbon content, measuring the fraction of bio-based carbon in a product compared to the total organic carbon content (Ladu and Blind, 2017).

Indicators of progress can be relevant at various levels of analysis (e.g. product, company, industry, municipality, region, and nation). Examples of macro/*meso*- level metrics for GE, and including various indicators representing the social, economic and ecological dimensions, are: the Global Green Economy Index (GGEI), promoted by private consultancy Dual Citizen (2021), and assessing perception and performance of progress of nations and cities; and the Green growth indicators framework by the OECD (2021), assessing progress at national level. Also related to GE is the Natural Capital Index, a policy-relevant indicator developed by the Netherlands Environmental Assessment Agency to assess changes in ecosystem quantity and quality (Davies et al., 2015; ten Brink et al., 2012). The System of Environmental-Economic Accounting (SEEA) by the United Nations Statistical Commission is an accounting framework consistent with the System of National Accounts (SNA), but measures natural capital and its socio-economic relevance. Ecosystem services assessments and accounting are also increasingly integrated at company-level, and while no specific metric is known to the authors, relevant guidelines and protocols are being developed (GRI, 2011; NCC, 2016).

Regarding CE, various metrics exist covering aspects at micro, meso and macro level (Moraga et al., 2019; Nikolaou et al., 2021; Saidani et al., 2019). An example at micro-level is the Material Circularity Indicator by the Ellen MacArthur Foundation (The Ellen MacArthur Foundation, 2015). At macro-level, the circularity rate, estimated at 9% for the global economy and 12% for the EU27 (Circle economy, 2018; Eurostat, 2020).

Potential BE metrics are only emerging, and literature suggests that comprehensive indicators sets should include multiple social and environmental impacts of the bioeconomy (D'Adamo et al., 2020; Karvonen et al., 2017; Wesseler and Von Braun, 2017), as well as considerations on the fossil-biomass substitution share (Jander and Grundmann, 2019).

It would also be important to assess how progress towards GE, CE and BE is reflected within cross-cutting metrics of sustainability, such as the Changing Wealth of Nations by the World Bank (Lange et al., 2018). Importantly, tools and indicators for GE, CE and BE must: a. represent progress in respect to multiple dimensions of sustainability; b. be able to capture both the absolute and relative effectiveness of individual strategies and actions; and c. be adaptable to varying spatial and temporal system boundaries, since the goal is global net sustainability now and in the long term, in the concentric system society- economy operating within the biosphere (see also Bastianoni et al., 2018).

5. Discussion

The conceptualization of the three narratives, GE, CE and BE, has been recognized in the literature to be both blurred and dynamic, due to two reasons. First, there is a strong technical orientation (engineering, environmental sciences) in the research environment, with less emphasis on reaching a shared understanding or comparing definitions (Korhonen et al., 2018a, 2018b; Sanz-Hernández et al., 2019; Toppinen et al., 2020). Consequently, in the literature regarding GE, CE or BE, there is often a call for 'more comprehensive and holistic approaches' (Geissdoerfer et al., 2017) (p. 757). Second, there is a multitude of societal actors using and contributing to the development of GE, CE and BE, resulting in an evolving internal diversity of interpretations and understandings (Bugge et al., 2016; Korhonen et al., 2018b; Merino-Saum et al., 2020). The breadth of the abstract framings of GE, CE or BE is foundational to informing the operationalization of strategies, actions and tools in public and private decision-making at national or regional level worldwide.

This study reveals that GE, CE and BE offer unique sustainability solutions (see 'actions' in Table 1), but based on our analysis of goal formulation (Tables 1 and 2), none of them offers a complete package of solutions. GE addresses societal needs through the idea of leveraging material and immaterial benefits from the ecosphere (and to an extent, from the lithosphere), but is limited in addressing the issue of societal outputs (especially beyond land use). CE proposes to reduce societal inputs and outputs by retaining retain the value embedded in material cycles for as long as possible, but still poorly addresses the role of natural capital and ecosystem services (although the 'regenerative' attribute of the circular economy described by the Ellen MacArthur foundation and by some scholars points to the conservation of natural resources (Alhawari et al., 2021)). BE promotes the substitution of lithosphere inputs with ecosphere inputs, but overlooks issues related to societal output. In terms of social dimension, both CE and BE place little emphasis on global North-South dynamics of resource flows (while there is more awareness of regional production-urban systems flows) and intra−/inter generational justice.

Overall, none of the three narratives has a clear stance regarding desirable levels of substitutability between natural capital and human-made capital. Although there is so far no evidence of successful absolute decoupling of economic growth from environmental impacts (Vadén et al., 2020; Ward et al., 2016), neither GE, CE nor BE explicitly address the duality of prosperity versus resource consumption. There is also space for progress of the three narratives in regard to equity, which is increasingly pointed out as indispensable in the context of sustainability transformations, and requires a deepening of the discussion about intra- and inter-generational disparities (e.g. related to class, gender, sexual identity, disabilities, ethnicity, geography) in the economic, social, cultural, political, spatial, environmental and cognitive spheres of being (Leach et al., 2018). Lack of discussion on growth and equity were also identified as significant gap areas in large-scale post-carbon economy transition strategies outlined by selected governamental and non-governamental documents (Wiseman et al., 2013).

The three narratives, GE, CE and BE are often discussed in a separate manner in both science and other realms, although the connection between CE and BE is increasingly solidifying in scientific and grey literature (Toppinen et al., 2020; Velenturf et al., 2019). While industrial symbiosis and efficiency of bio-based resources are currently foundational ideas to CEBE, it would be important to also consider socio-ecological circularity beyond industrial systems. The interface of CE and GE is also a crucial place for research to explore (e.g. Atanasova et al., 2021; Buchmann-Duck and Beazley, 2020). This could build on existing ideas of ecotechnology and biomimicry, where combined natural or artificial systems can serve functions and solve problems in industrial and urban systems (see also nature-based solutions). The connection between GE and BE would also benefit from further examination, and potential avenues are territorial resilience (see also biosecurity) and management, including multifunctionality and risks in environmental and productive systems.

Moreover, the notion of narrative (D'Amato, 2021) can be further refined and used to investigate less politically mainstream or otherwise emerging narratives. In this regard, we here signal postgrowth-related narratives (e.g. Belmonte-Ureña et al., 2021), as well as the emergence, from the realm of sustainable business and financing, of a new term 'nature-positive economy' (Loorbach et al., 2020; World Economic Forum and AlphaBeta, 2020). Other needed considerations regard the feasibility and legitimacy of narratives as sustainability pathways, including maturity (technical, socio-cultural, organizational, institutional), infrastructures requirements and integration, societal and political acceptability, as well as the role of various actors of change (Turnheim and Nykvist, 2019).

6. Conclusions

This study provides a comparative analysis of the green, circular and bioeconomy in terms of their respective and joint potential for global net sustainability. The complementary contribution of the three narratives, interpreted based on their most inclusive conceptualization, could be formulated as follows:

> *Jointly, the circular economy, the green economy and the bioeconomy show the need for a new global society and economy to be based on renewable/reproductive, biodiversity-based and biodiversity-benign processes, delivering material and immaterial benefits that fulfil the economic and social requirements of all people now and in the future.*

However, if the operationalization of the three narratives, individually or jointly, is conducted without considering global net sustainability, problem displacement, cascade effects, problem shifting, rebound effects and other undesired or unexpected effects may occur in practice, thus limiting effectiveness of actions. Finally, while the complementary contribution of these three narratives provides important guidelines, these are possibly still incomplete and insufficient for progressing towards global net sustainability.

Sustainability narratives, such as GE, CE and BE, are recurrently used to frame sustainability challenges and to operationalize solutions by researchers, managers, consultants, policy-makers or other decision-makers and their organizations at local, national and international level. We therefore outline two sets of implications, for (i) researchers (and for (ii) other professionals working with sustainability transformations or more generally dealing with sustainability issues.

i. More research is needed to explicitly address and understand complementarities and incompatibilities between green, circular and bioeconomy solutions. Further, we suggest that explorative analyses are needed to identify additional existing or emerging narratives or concepts that could complement and supplement currently mainstreamed solutions towards post-Covid-19 sustainability transformations. Efforts should be oriented towards combining multiple compatible solutions – including, among others, circularity, bio-based and other sustainability innovations, ecosystem stewardship and nature-based solutions, sharing of products/services, responsible consumption, sufficiency and frugality – and considering applicability and scalability across systems worldwide, such as, for example, production systems, cities, infrastructures and mobility, energy and extractives.
ii. In order to improve the effectiveness of action at practical implementation level, our conclusive recommendations is to develop coherent decision-making strategies, actions and tools/indicators that take into consideration solutions based on multiple sustainability narratives, including GE, CE and BE, and potentially others. We further suggest that when mobilizing GE, CE, BE or other narratives, whether individually or jointly, these should be solidly framed in the context of overarching international processes (e.g. the Sustainable Development Goals), and from the perspective of global net sustainability. This is especially important in order to identify and address undesired or suboptimal outcomes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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